The Tools of Research

A former director of the Peoria laboratory explained in one sentence his formula for obtaining satisfactory research results. "Employ the most competent scientists you can find," he said, "supply them with the best scientific instruments and equipment, explain your research goals, and then back off and let them work."

The "best" in laboratory tools when the regional labs began was a far cry from the instruments of the 1990's. The equipment in the regional laboratories in the 1940's was made mostly of glass and wood and brass. Only the glassware would appear familiar to a young scientist today: Petri dishes and flasks and beakers and condensers. The old-fashioned microscope with its brass fittings and the wooden box of apparatus for blowing glass would look like museum pieces. Computers? A slide rule lay on every bench.

Today the typical laboratory in any of the four centers is filled with what researchers call black boxes. Most are electronic devices, and their color is more likely to be metallic silver than black. They bristle with switches and dials and tubes. It's unlikely that the 1940 chemist would have had any idea what to do with them, but they are indispensable to the 1990 researcher. Particularly as analytical tools, they make it possible to ask many questions—and to answer them—that couldn't even have been considered 50 years ago.

While few of the instruments were invented in the regional labs, the scientists there have used them in many new ways and develop important new techniques of analysis. An example is chromatography, a technique that began to be used at the centers in the late 1940's. A chromatograph separates mixtures of substances and enables the chemist to discover what compounds are in them and in what amounts. It replaced painfully slow, one-compound-at-a-time analysis using qualitative and quantitative methods. One form of the technique, gas-liquid chromatography, enables a chemist to identify the chemical compounds present in a gas or in a substance that has been converted to gas by heating.

Scientists at the Western laboratory in 1954 became the first to use gas-liquid chromatography for the study of volatile organic substances in foods. To accomplish this, they made several improvements in the technique, including increasing its resolution. This in turn led to coupling the gas chromatograph to another instrument called a fast-scan mass spectrometer. This is an electronic tool for analyzing gases that provides positive identification of mere traces of substances. The contributions of these WRRC researchers to the art of identifying the most minute constituents of complex mixtures have since been recognized by scientists all over the world.

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One basic analytical technique, known as thin-layer chromatography, was invented at the ARS laboratory in Pasadena, then a field lab of the WRRC. Using a method described by scientific reviewers as "elegant," two researchers modified a technique known as paper chromatography by substituting glass plates for the paper. A thin layer of a powdered adsorbent was bonded to the plate, which was used in a simple procedure that proved fast, convenient, sensitive, and reliable. First developed in the 1950's to identify the flavoring components of citrus fruit, its use expanded sharply in 1957, when commercial equipment became available in Europe for making the thin-layer plates. Soon it was the most popular chromatographic process, and it was used to analyze inorganic as well as organic materials. One scientist

commented: "The technique is a nearly perfect, universal analytical tool that allows research workers to obtain answers in minutes instead of hours."

Methods are further modified and improved over the years to meet specific needs. The Eastern lab developed a practical device for carrying out chromatography continuously—an invention which found many practical applications in industry. ERRC also simplified the isolation of fats from food with a dry column method of chromatography. It became the preferred method at the Eastern lab for analyzing dairy products, poultry and eggs, fish, and pet food. In Peoria, researchers made use of high-performance liquid chromatography in monitoring fermentation byproducts in making ethanol for fuel.

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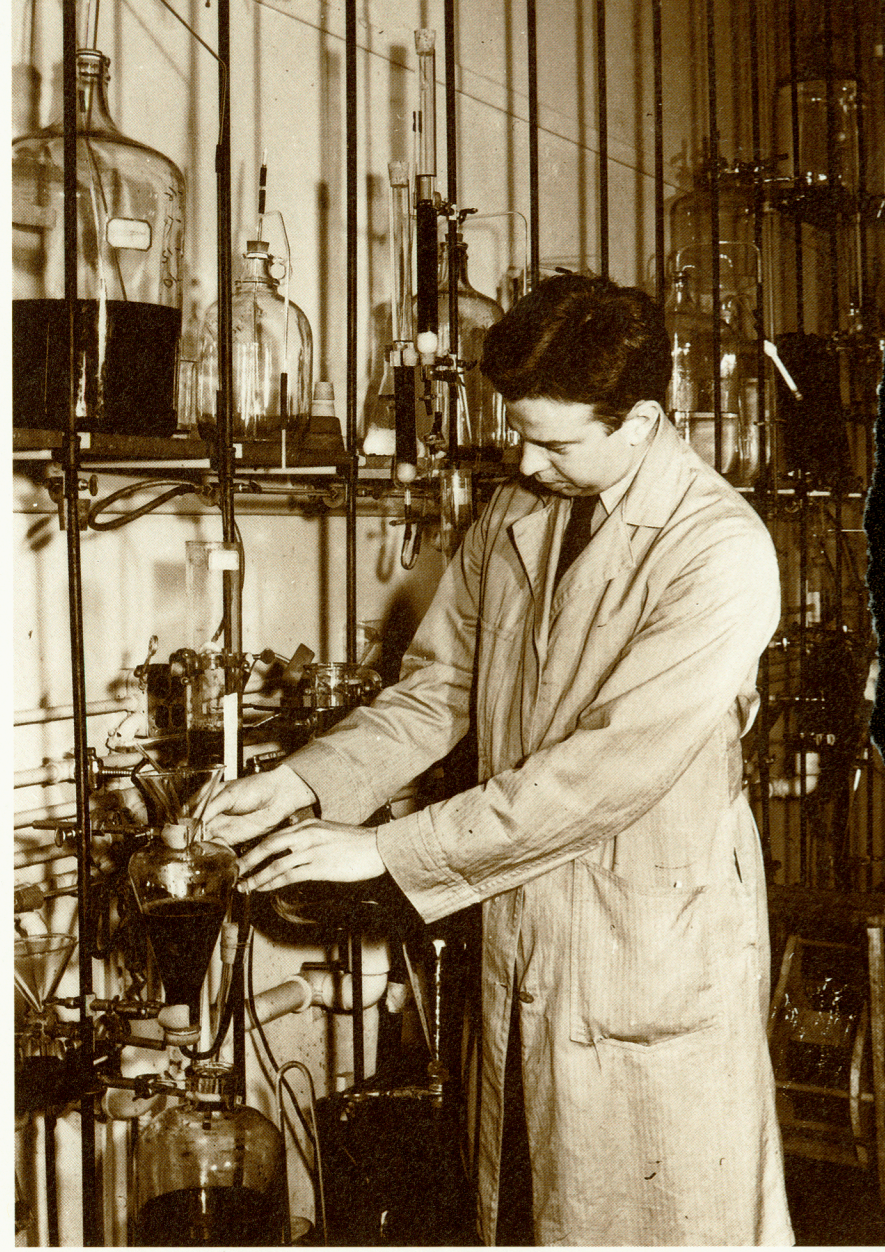
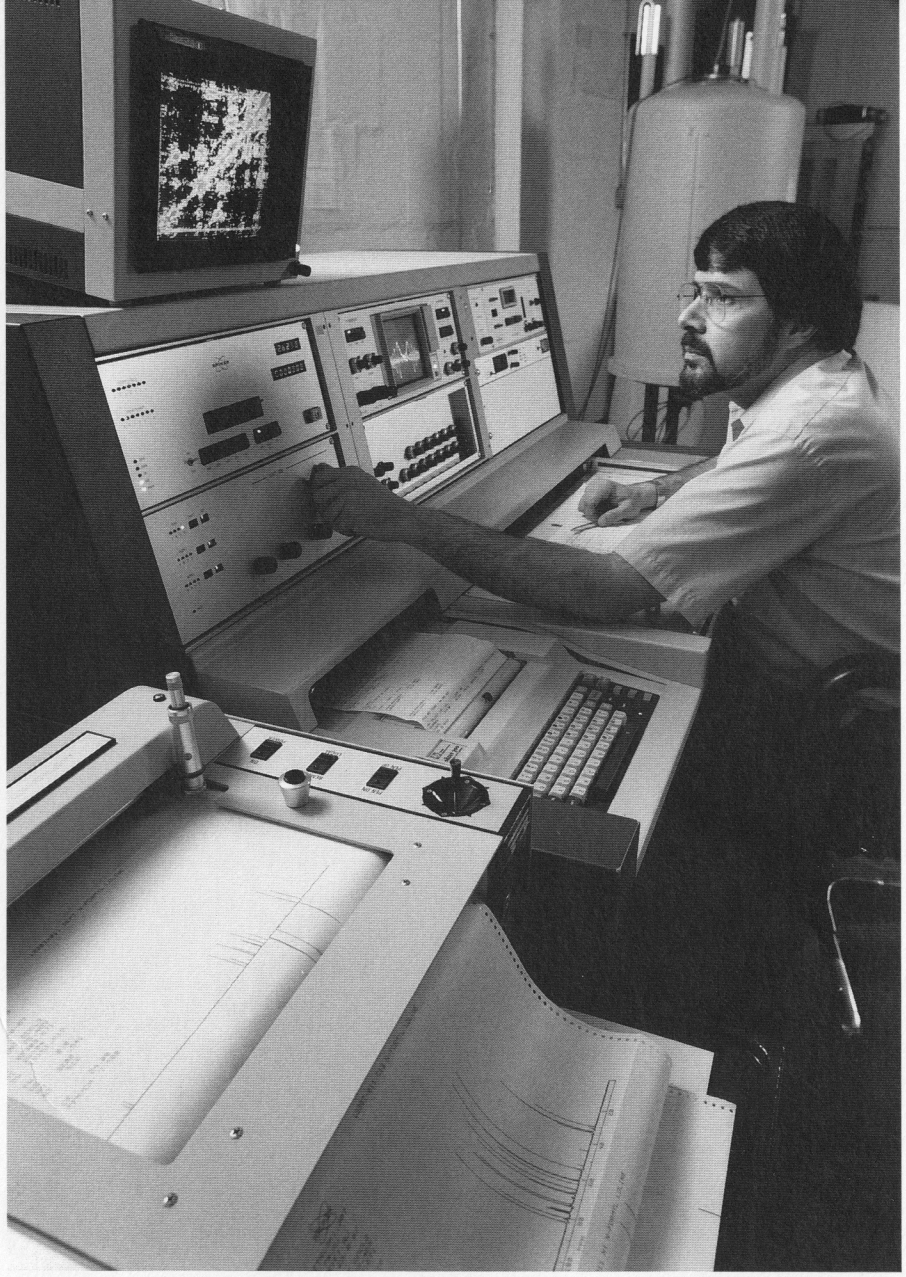
In 1950, the Eastern lab designed and built the first light-scattering instrument, called a diffusion photometer, for measuring the size of molecules. The invention was later commercialized under the Brice-Phoenix label and became a standard instrument for studying polymers. In the 1960's, ERRC developed a novel small-angle X-ray scattering instrument that allows scientists to explore such phenomena as the flow behavior of proteins in solution. Recently, the device enabled researchers to explain the calcium-controlled relationships between casein particles and subparticles in making cheese. The research is crucial to the manufacture of better dairy products.

Another important invention of the last 50 years is the scanning electron microscope, which is used to examine the surface of solid objects at magnifications as high as 200,000 times. Unlike an optical microscope, it uses a high-energy beam of electrons instead of ordinary light to form an image. These images, which resemble the picture on a television set, have great depth of field. The scanning electron microscope has been used by regional scientists for countless purposes.

The Southern lab, for example, began using the scanning electron microscope in the early 1970's for direct and detailed observation of the surfaces of cotton fabrics. It became possible for the first time to compare the surface appearances of chemically treated and untreated fabrics, before and after abrasion. A



In 1946 in the Western lab, C.C. Nimmo conducts research to recover tartaric acid directly from grape brandy waste.



More than 40 years later, Peoria chemist David Weisleder uses magnetic resonance imaging to identify pesticides occurring in plant materials.

few years later, SRRC scientists improved the technique by combining scanning electron microscopy with energy-dispersive X-ray analysis. This powerful combination of tools enabled researchers to observe not only the individual fibers of treated cotton, but also precisely where the treating chemicals had lodged.

In Peoria, an examination of 33 soybean varieties with a scanning electron microscope revealed wide differences in seed-coat structure. This unexpected diversity should help soybean breeders to develop varieties with seed coats that resist cracking. Cracked seeds are an open invitation to invasion by microorganisms during storage.

Other new chemistry tools borrowed from physics include infrared spectroscopy, for many years the only instrumental technique available to chemists for molecular analysis. ERRC scientists in the early 1950's used it to study and identify hormones and vitamins, as well as a broad range of steroids related to cholesterol. Later, ERRC devised a new method, called differential isotope shift spectroscopy, for determining the arrangement of carbon atoms in sugars.

One of the most useful research tools is nuclear magnetic resonance, which is also used as a diagnostic aid in human medicine. NMR allows scientists to look at a cross section of a living plant or animal without having to cut into it or subject it to X-rays. The system creates images from low-energy radio waves, which are harmless to the subject. The Western lab built an NMR machine in the 1950's, and the other labs subsequently purchased their own.

At the Eastern center, the techniques have been applied to a study of the enzymes involved in the transport of nutrients in the root of a plant. For the first time, scientists have been able to find out what happens inside a living cell when it takes up nutrients under various environmental conditions. One researcher has said such information is essential "to develop new varieties of crops designed for low-input, environmentally safe farming practices."